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**TITLE OF THE INVENTION (280 characters max)**

**M3 MUSCARINIC ACETYLCHOLINE RECEPTOR ANTAGONISTS**

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**ENCLOSED APPLICATION PARTS (check all that apply)**

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**METHOD OF PAYMENT OF FILING FEES FOR THIS PROVISIONAL APPLICATION FOR PATENT**

<input checked="" type="checkbox"/> The Commissioner is hereby authorized to charge filing fees and credit Deposit Account No. <b>19-2570</b>	<b>PROVISIONAL FILING FEE AMOUNT (\$)</b>	<b>\$160.00</b>
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Respectfully submitted,  
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Date:

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☐ Additional inventors are being named on separately numbered sheets attached hereto.

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**20462**

CUSTOMER NUMBER

## **M<sub>3</sub> MUSCARINIC ACETYLCHOLINE RECEPTOR ANTAGONISTS**

### **FIELD OF THE INVENTION**

This invention relates to novel derivatives of 8-azoniabicyclo [3,2,1]octanes, pharmaceutical compositions, processes for their preparation, and use thereof in treating M<sub>3</sub> muscarinic acetylcholine receptor mediated diseases.

### **BACKGROUND OF THE INVENTION**

Acetylcholine released from cholinergic neurons in the peripheral and central nervous systems affects many different biological processes through interaction with two major classes of acetylcholine receptors – the nicotinic and the muscarinic acetylcholine receptors. Muscarinic acetylcholine receptors (mAChRs) belong to the superfamily of G-protein coupled receptors that have seven transmembrane domains. There are five subtypes of mAChRs, termed M<sub>1</sub>-M<sub>5</sub>, and each is the product of a distinct gene. Each of these five subtypes displays unique pharmacological properties. Muscarinic acetylcholine receptors are widely distributed in vertebrate organs, and these receptors can mediate both inhibitory and excitatory actions. For example, in smooth muscle found in the airways, bladder and gastrointestinal tract, M<sub>3</sub> mAChRs mediate contractile responses. For review, please see {Brown 1989 247 /id}.

Muscarinic acetylcholine receptor dysfunction has been noted in a variety of different pathophysiological states. For instance, in asthma and chronic obstructive pulmonary disease (COPD), inflammatory conditions lead to loss of inhibitory M<sub>2</sub> muscarinic acetylcholine autoreceptor function on parasympathetic nerves supplying the pulmonary smooth muscle, causing increased acetylcholine release following vagal nerve stimulation. This mAChR dysfunction results in airway hyperreactivity mediated by increased stimulation of M<sub>3</sub> mAChRs{Costello, Evans, et al. 1999 72 /id}{Minette, Lammers, et al. 1989 248 /id}. Similarly, inflammation of the gastrointestinal tract in inflammatory bowel disease (IBD) results in M<sub>3</sub>

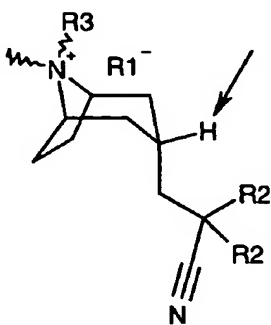
mAChR-mediated hypermotility {Oprins, Meijer, et al. 2000 245 /id}. Incontinence due to bladder hypercontractility has also been demonstrated to be mediated through increased stimulation of M<sub>3</sub> mAChRs {Hegde & Eglen 1999 251 /id}. Thus the identification of subtype-selective mAChR antagonists may be useful as therapeutics in these mAChR-mediated diseases.

Despite the large body of evidence supporting the use of anti-muscarinic receptor therapy for treatment of a variety of disease states, relatively few anti-muscarinic compounds are in use in the clinic. Thus, there remains a need for novel compounds that are capable of causing blockade at M<sub>3</sub> mAChRs. Conditions associated with an increase in stimulation of M<sub>3</sub> mAChRs, such as asthma, COPD, IBD and urinary incontinence would benefit by compounds that are inhibitors of mAChR binding.

### **SUMMARY OF THE INVENTION**

This invention provides for a method of treating a muscarinic acetylcholine receptor (mAChR) mediated disease, wherein acetylcholine binds to an M<sub>3</sub> mAChR and which method comprises administering an effective amount of a compound of Formula (I) or a pharmaceutically acceptable salt thereof.

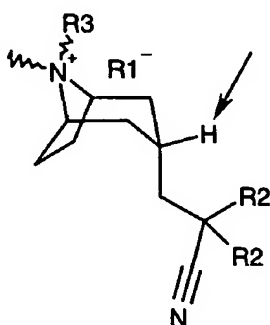
This invention also relates to a method of inhibiting the binding of acetylcholine to its receptors in a mammal in need thereof which comprises administering to aforementioned mammal an effective amount of a compound of Formula (I).



(I)

## **DETAILED DESCRIPTION OF THE INVENTION**

This invention relates to novel derivatives of 8-azoniabicyclo [3,2,1]octanes, pharmaceutical compositions, processes for their preparation, and use thereof in treating M<sub>3</sub> muscarinic acetylcholine receptor mediated diseases.



(I)

Compounds with Formula (I) are preferred, wherein:

The H atom indicated is in the exo position;

R<sup>1</sup><sup>-</sup> represents an anion associated with the positive charge of the N atom. R<sup>1</sup><sup>-</sup> may be but is not limited to chloride, bromide, iodide, sulfate, benzene sulfonate and toluene sulfonate;

R<sup>2</sup> is selected from the group consisting of straight or branched chain lower alkyl groups (having preferably from 1 to 6 carbon atoms), cycloalkyl groups (having from 5 to 6 carbon atoms), cycloalkyl-alkyl (having 6 to 10 carbon atoms), heterocycloalkyl (having 5 to 6 carbon atoms) and N or O as the heteroatom, heterocycloalkyl-alkyl (having 6 to 10 carbon atoms) and N or O as the heteroatom, aryl, optionally substituted aryl, heteroaryl, and optionally substituted heteroaryl;

R3 is selected from the group consisting of (C<sub>2</sub>-C<sub>12</sub>)alkyl, (C<sub>1</sub>-C<sub>6</sub>)alkenyl, (C<sub>1</sub>-C<sub>6</sub>)alkyl(C<sub>3</sub>-C<sub>6</sub>)cycloalkyl, (C<sub>1</sub>-C<sub>6</sub>)alkyl-phenyl, (C<sub>1</sub>-C<sub>6</sub>)alkyl-OH, (C<sub>1</sub>-C<sub>6</sub>)alkyl-CN, (C<sub>1</sub>-C<sub>6</sub>)alkyl-halogen, (C<sub>1</sub>-C<sub>6</sub>)alkyl-CF<sub>3</sub>, (C<sub>1</sub>-C<sub>6</sub>)alkyl-OCH<sub>3</sub>, (C<sub>1</sub>-C<sub>6</sub>)alkyl-O-(C<sub>1</sub>-C<sub>6</sub>)alkyl-OCH<sub>3</sub>.

All of the aryl, heteroaryl, and heterocyclic containing moieties may be optionally substituted as defined herein below.

For use herein the term "the aryl, heteroaryl, and heterocyclic containing moieties" refers to both the ring and the alkyl, or if included, the alkenyl rings, such as aryl, arylalkyl, and aryl alkenyl rings. The term "moieties" and "rings" may be interchangeably used throughout.

As used herein, "optionally substituted" unless specifically defined shall mean such groups as halogen, such as fluorine, chlorine, bromine or iodine; hydroxy; hydroxy substituted C<sub>1</sub>-10alkyl; C<sub>1</sub>-10 alkoxy, such as methoxy or ethoxy; S(O)<sub>m'</sub> C<sub>1</sub>-10 alkyl, wherein m' is 0, 1 or 2, such as methyl thio, methyl sulfinyl or methyl sulfonyl; amino, mono & di-substituted amino, such as in the NR<sub>4</sub>R<sub>5</sub> group; NHC(O)R<sub>4</sub>; C(O)NR<sub>4</sub>R<sub>5</sub>; C(O)OH; S(O)<sub>2</sub>NR<sub>4</sub>R<sub>5</sub>; NHS(O)<sub>2</sub>R<sub>4</sub>, C<sub>1</sub>-10 alkyl, such as methyl, ethyl, propyl, isopropyl, or t-butyl; halosubstituted C<sub>1</sub>-10 alkyl, such as CF<sub>3</sub>; an optionally substituted aryl, such as phenyl, or an optionally substituted arylalkyl, such as benzyl or phenethyl, optionally substituted heterocyclic, optionally substituted heterocyclicalkyl, optionally substituted heteroaryl, optionally substituted heteroaryl alkyl, wherein these aryl, heteroaryl, or heterocyclic moieties may be substituted one to two times by halogen; hydroxy; hydroxy substituted alkyl; C<sub>1</sub>-10 alkoxy; S(O)<sub>m'</sub>C<sub>1</sub>-10 alkyl; amino, mono & di-substituted alkyl amino, such as in the NR<sub>4</sub>R<sub>5</sub> group; C<sub>1</sub>-10 alkyl, or halosubstituted C<sub>1</sub>-10 alkyl, such as CF<sub>3</sub>.

Suitable pharmaceutically acceptable salts are well known to those skilled in the art and include basic salts of inorganic and organic acids, such as hydrochloric acid, hydrobromic acid, sulphuric acid, phosphoric acid, methane sulphonic acid, ethane sulphonic acid, acetic acid, malic acid, tartaric acid, citric acid, lactic acid, oxalic acid, succinic acid, fumaric acid,

maleic acid, benzoic acid, salicylic acid, phenylacetic acid and mandelic acid. In addition, pharmaceutically acceptable salts of compounds of Formula (I) may also be formed with a pharmaceutically acceptable cation. Suitable pharmaceutically acceptable cations are well known to those skilled in the art and include alkaline, alkaline earth, ammonium and quaternary ammonium cations.

The following terms, as used herein, refer to:

- "halo" - all halogens, that is chloro, fluoro, bromo and iodo.
- "C<sub>1-10</sub>alkyl" or "alkyl" - both straight and branched chain moieties of 1 to 10 carbon atoms, unless the chain length is otherwise limited, including, but not limited to, methyl, ethyl, *n*-propyl, *iso*-propyl, *n*-butyl, *sec*-butyl, *iso*-butyl, *tert*-butyl, *n*-pentyl and the like.
- "cycloalkyl" is used herein to mean cyclic moiety, preferably of 3 to 8 carbons, including but not limited to cyclopropyl, cyclopentyl, cyclohexyl, and the like.
- "alkenyl" is used herein at all occurrences to mean straight or branched chain moiety of 2-10 carbon atoms, unless the chain length is limited thereto, including, but not limited to ethenyl, 1-propenyl, 2-propenyl, 2-methyl-1-propenyl, 1-butenyl, 2-butenyl and the like.
- "aryl" - phenyl and naphthyl;
- "heteroaryl" (on its own or in any combination, such as "heteroaryloxy", or "heteroaryl alkyl") - a 5-10 membered aromatic ring system in which one or more rings contain one or more heteroatoms selected from the group consisting of N, O or S, such as, but not limited, to pyrrole, pyrazole, furan, thiophene, quinoline, isoquinoline, quinazolinyl, pyridine, pyrimidine, oxazole, tetrazole, thiazole, thiadiazole, triazole, imidazole, or benzimidazole.
- "heterocyclic" (on its own or in any combination, such as "heterocyclicalkyl" or "heterocycloalkyl") - a saturated or partially unsaturated 4-10 membered ring system in which one or more rings contain one or more heteroatoms selected from the group consisting of N, O, or S; such as, but not limited to, pyrrolidine, piperidine, piperazine, morpholine,

tetrahydropyran, thiomorpholine, or imidazolidine. Furthermore, sulfur may be optionally oxidized to the sulfone or the sulfoxide.

- "arylalkyl" or "heteroarylalkyl" or "heterocyclicalkyl" is used herein to mean C<sub>1-10</sub> alkyl, as defined above, attached to an aryl, heteroaryl or heterocyclic moiety, as also defined herein, unless otherwise indicated.

- "sulfinyl" - the oxide S (O) of the corresponding sulfide, the term "thio" refers to the sulfide, and the term "sulfonyl" refers to the fully oxidized S(O)<sub>2</sub> moiety.

- Preferred compounds useful in the present invention include:

(3-endo)-3-(2-cyano-2,2-diphenylethyl)-8-(cyclohexylmethyl)-8-methyl-8-azoniabicyclo[3.2.1]octane bromide;

(3-endo)-3-(2-cyano-2,2-diphenylethyl)-8-(cyclopropylmethyl)-8-methyl-8-azoniabicyclo[3.2.1]octane bromide;

(3-endo)-8-butyl-3-(2-cyano-2,2-diphenylethyl)-8-methyl-8-azoniabicyclo[3.2.1]octane bromide;

(3-endo)-8-(4-chlorobutyl)-3-(2-cyano-2,2-diphenylethyl)-8-methyl-8-azoniabicyclo[3.2.1]octane bromide;

(3-endo)-3-(2-cyano-2,2-diphenylethyl)-8-dodecyl-8-methyl-8-azoniabicyclo[3.2.1]octane bromide;

(3-endo)-3-(2-cyano-2,2-diphenylethyl)-8-methyl-8-(2-propen-1-yl)-8-azoniabicyclo[3.2.1]octane iodide;

(3-endo)-3-(2-cyano-2,2-diphenylethyl)-8-methyl-8-(phenylmethyl)-8-azoniabicyclo[3.2.1]octane bromide;

(3-endo)-3-(2-cyano-2,2-diphenylethyl)-8-(2-hydroxyethyl)-8-methyl-8-azoniabicyclo[3.2.1]octane bromide;

(3-endo)-3-(2-cyano-2,2-diphenylethyl)-8-ethyl-8-methyl-8-azoniabicyclo[3.2.1]octane bromide;

(3-endo)-3-(2-cyano-2,2-diphenylethyl)-8-methyl-8-propyl-8-azoniabicyclo[3.2.1]octane bromide;

(3-endo)-3-(2-cyano-2,2-diphenylethyl)-8-(5-hexen-1-yl)-8-methyl-8-azoniabicyclo[3.2.1]octane bromide;



(3-endo)-3-(2-cyano-2,2-diphenylethyl)-8-methyl-8-(4,4,4-trifluorobutyl)-8-azoniabicyclo[3.2.1]octane bromide;

(3-endo)-3-(2-cyano-2,2-diphenylethyl)-8-methyl-8-(3-phenylpropyl)-8-azoniabicyclo[3.2.1]octane bromide;

(3-endo)-3-(2-cyano-2,2-diphenylethyl)-8-(2-cyclohexylethyl)-8-methyl-8-azoniabicyclo[3.2.1]octane bromide;

(3-endo)-3-(2-cyano-2,2-diphenylethyl)-8-(3-cyanopropyl)-8-methyl-8-azoniabicyclo[3.2.1]octane bromide;

(3-endo)-3-(2-cyano-2,2-diphenylethyl)-8-methyl-8-[2-(methyloxy)ethyl]-8-azoniabicyclo[3.2.1]octane bromide; and

(3-endo)-3-(2-cyano-2,2-diphenylethyl)-8-methyl-8-(2-[[2-(methyloxy)ethyl]oxy]ethyl)-8-azoniabicyclo[3.2.1]octane bromide.

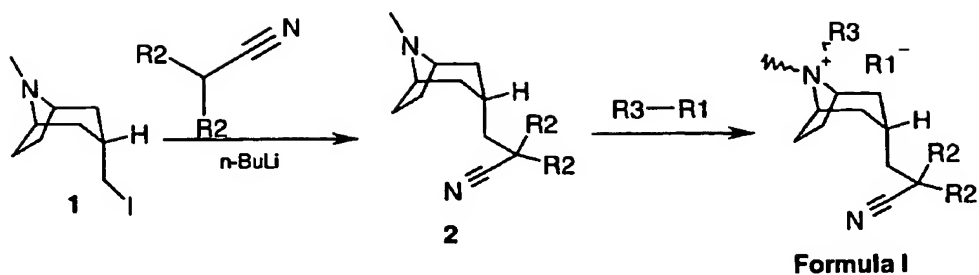
### **Methods of Preparation**

#### **Preparation**

The compounds of Formula (I) may be obtained by applying synthetic procedures, some of which are illustrated in the Schemes below. The synthesis provided for these Schemes is applicable for producing compounds of Formula (I) having a variety of different R<sub>1</sub>, R<sub>2</sub> and R<sub>3</sub> which are reacted, employing substituents which are suitable protected, to achieve compatibility with the reactions outlined herein. Subsequent deprotection, in those cases, then affords compounds of the nature generally disclosed. While some Schemes are shown with specific compounds, this is merely for illustration purpose only.

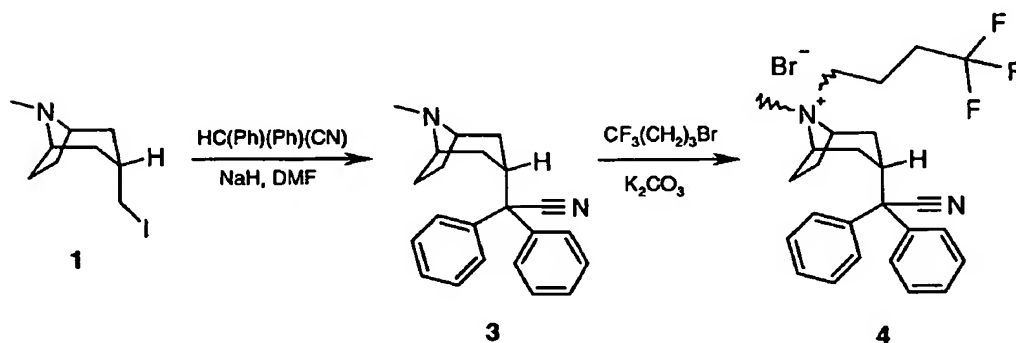
The general preparation method is shown in **Scheme I**. The synthesis started with compound 1. Coupling reaction with the anion derived from HC(CN)(R<sub>2</sub>)(R<sub>2</sub>) provided 2. Treatment with R<sub>3</sub>-R<sub>1</sub> then furnished the quaternary ammonium salt with Formula (I).

**Scheme I.**



A more specific preparation method leading to compounds with Formula (I) is outlined in **Scheme II**. Alkylation of diphenylacetonitrile with **1** afforded compound **3**. Treatment with  $\text{CF}_3(\text{CH}_2)_3\text{Br}$  then afforded quaternary ammonium salt **4**.

**Scheme II**



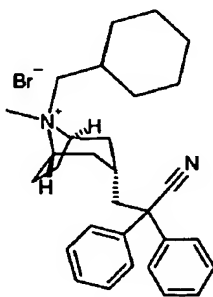
## SYNTHETIC EXAMPLES

The following examples are provided as illustrative of the present invention but not limiting in any way:

## General Preparation Procedures

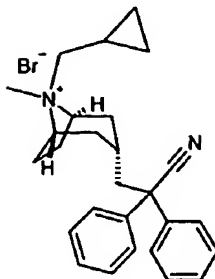
A solution of 3-((3-endo)-8-methyl-8-aza-bicyclo[3.2.1]oct-3-yl)-2,2-diphenyl-propionitrile (33.0 mg, 0.10 mmol) in CH<sub>2</sub>Cl<sub>2</sub> (0.5 mL) and MeCN (0.5 mL) was mixed with RBr (1.0 mmol) and K<sub>2</sub>CO<sub>3</sub> (27.6 mg, 0.20 mmol). The resultant mixture was stirred at room temperature for certain reaction time (specified in following examples). It was then diluted with DMSO (0.3 mL) and concentrated. Purification via a reverse phase HPLC (Gilson) afforded the target compound.

### Example 1



(3-endo)-3-(2-cyano-2,2-diphenylethyl)-8-(cyclohexylmethyl)-8-methyl-8-azoniabicyclo[3.2.1]octane bromide The title compound was prepared in 15% yield by following the general experimental procedure (reaction time = 7 days): LCMS (ES)  $m/z$  427 (M)<sup>+</sup>; <sup>1</sup>H-NMR(CDCl<sub>3</sub>) δ 1.29 (m, 3H), 1.43 (m, 2H), 1.83 (m, 8H), 2.19 (m, 1H), 2.42 (m, 6H), 3.00 (m, 2H), 3.04 (s, 3H), 3.10 (d, 2H), 3.84 (s, 2H), 7.35 (m, 2H), 7.43 (m, 4H), 7.49 (m, 4H).

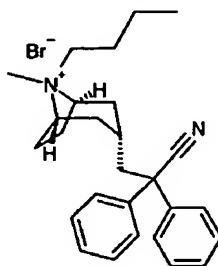
### Example 2



(3-endo)-3-(2-cyano-2,2-diphenylethyl)-8-(cyclopropylmethyl)-8-methyl-8-azoniabicyclo[3.2.1]octane bromide

The title compound was prepared in 51% yield by following the general experimental procedure (reaction time = 70 hours): LCMS (ES)  $m/z$  385 (M)<sup>+</sup>; <sup>1</sup>H-NMR(CDCl<sub>3</sub>)  $\delta$  0.48 (m, 2H), 0.83 (m, 2H), 1.13 (m, 1H), 1.82 (m, 2H), 2.22 (m, 1H), 2.42 (m, 6H), 3.01 (m, 2H), 3.12 (m, 3H), 3.19 (d, 2H), 3.90 (m, 2H), 7.35 (m, 2H), 7.43 (m, 4H), 7.50 (m, 4H).

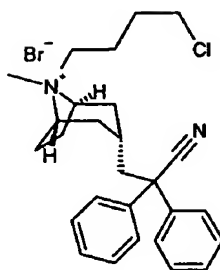
### Example 3



(3-endo)-8-butyl-3-(2-cyano-2,2-diphenylethyl)-8-methyl-8-azoniabicyclo[3.2.1]octane bromide

The title compound was prepared in 26% yield by following the general experimental procedure (reaction time = 70 hours): LCMS (ES)  $m/z$  387 (M)<sup>+</sup>; <sup>1</sup>H-NMR(CDCl<sub>3</sub>)  $\delta$  1.04 (m, 3H), 1.45 (m, 2H), 1.74 (m, 2H), 1.84 (d, 2H), 2.21 (m, 1H), 2.45 (m, 6H), 3.00 (m, 2H), 3.02 (s, 3H), 3.20 (m, 2H), 3.83 (s, 2H), 7.35 (m, 2H), 7.42 (m, 4H), 7.49 (m, 4H).

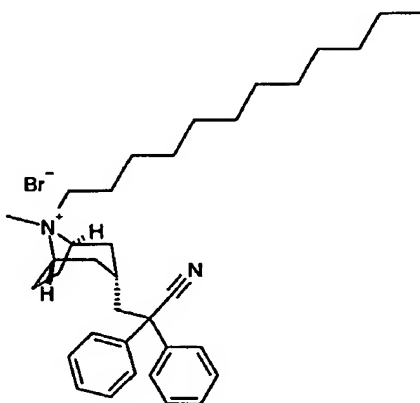
#### Exempl 4



(3-endo)-8-(4-chlorobutyl)-3-(2-cyano-2,2-diphenylethyl)-8-methyl-8-azoniabicyclo[3.2.1]octane bromide

The title compound was prepared in 37% yield by following the general experimental procedure (reaction time = 70 hours): LCMS (ES)  $m/z$  421 ( $M$ )<sup>+</sup>; <sup>1</sup>H-NMR(CDCl<sub>3</sub>)  $\delta$  1.88 (m, 6H), 2.18 (m, 1H), 2.45 (m, 6H), 3.01 (m, 2H), 3.04 (s, 3H), 3.28 (m, 2H), 3.67 (m, 2H), 3.84 (s, 2H), 7.35 (m, 2H), 7.42 (m, 4H), 7.49 (m, 4H).

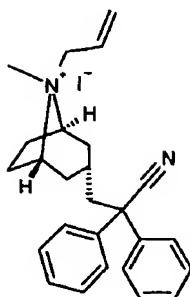
#### Example 5



(3-endo)-3-(2-cyano-2,2-diphenylethyl)-8-dodecyl-8-methyl-8-azoniabicyclo[3.2.1]octane bromide

The title compound was prepared in 10% yield by following the general experimental procedure (reaction time = 70 hours): LCMS (ES)  $m/z$  499 ( $M$ )<sup>+</sup>; <sup>1</sup>H-NMR(CDCl<sub>3</sub>)  $\delta$  0.95 (t, 3H), 1.36 (m, 18H), 1.73 (m, 2H), 1.82 (d, 2H), 2.18 (m, 1H), 2.46 (m, 6H), 3.00 (d, 2H), 3.02 (s, 3H), 3.19 (m, 2H), 3.82 (s, 2H), 7.35 (m, 2H), 7.42 (m, 4H), 7.49 (m, 4H).

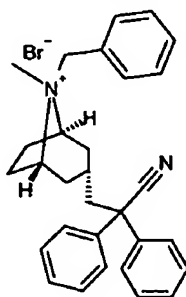
### Exempl 6



(3-endo)-3-(2-cyano-2,2-diphenylethyl)-8-methyl-8-(2-propen-1-yl)-8-azoniabicyclo[3.2.1]octane iodide

The title compound was prepared in 37% yield by following the general experimental procedure (reaction time = 3 hours): LCMS (ES)  $m/z$  371 ( $M^+$ );  $^1\text{H-NMR}(\text{CDCl}_3)$   $\delta$  1.83 (m, 2H), 2.20 (m, 1H), 2.36 (m, 2H), 2.47 (m, 4H), 3.02 (m, 5H), 3.85 (s, 2H), 3.92 (d, 2H), 5.71 (m, 2H), 6.09 (m, 1H), 7.35 (m, 2H), 7.42 (m, 4H), 7.51 (m, 4H).

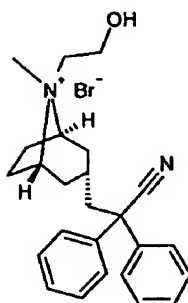
### Example 7



(3-endo)-3-(2-cyano-2,2-diphenylethyl)-8-methyl-8-(phenylmethyl)-8-azoniabicyclo[3.2.1]octane bromide

The title compound was prepared in 39% yield by following the general experimental procedure (reaction time = 3 hours): LCMS (ES)  $m/z$  421 ( $M^+$ );  $^1\text{H-NMR}(\text{CDCl}_3)$   $\delta$  1.85 (d, 2H), 2.17 (m, 1H), 2.45 (m, 4H), 2.73 (m, 2H), 2.92 (s, 3H), 3.04 (d, 2H), 3.86 (s, 2H), 4.45 (s, 2H), 7.34 (m, 2H), 7.42 (m, 4H), 7.48 (m, 4H), 7.56 (m, 5H).

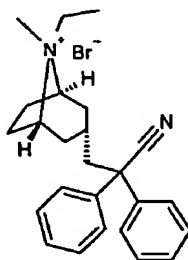
### Example 8



(3-endo)-3-(2-cyano-2,2-diphenylethyl)-8-(2-hydroxyethyl)-8-methyl-8-azoniabicyclo[3.2.1]octane bromide

The title compound was prepared in 40% yield by following the general experimental procedure (reaction time = 10 days): LCMS (ES)  $m/z$  375 (M)<sup>+</sup>; <sup>1</sup>H-NMR(CDCl<sub>3</sub>)  $\delta$  1.84 (m, 2H), 2.04 (m, 1H), 2.22 (m, 2H), 2.34 (m, 2H), 2.50 (m, 2H), 2.74 (s, 1H), 2.95 (d, 1H), 3.01 (d, 1H), 3.14 (s, 1H), 3.33 (s, 3H), 3.40 (m, 1H), 3.81 (m, 1H), 3.99 (m, 2H), 7.35 (m, 2H), 7.42 (m, 4H), 7.48 (m, 4H).

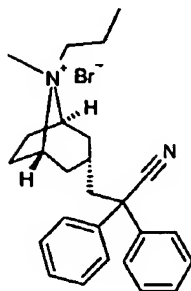
### Example 9



(3-endo)-3-(2-cyano-2,2-diphenylethyl)-8-ethyl-8-methyl-8-azoniabicyclo[3.2.1]octane bromide

The title compound was prepared in 60% yield by following the general experimental procedure (reaction time = 70 hours): LCMS (ES)  $m/z$  359 (M)<sup>+</sup>; <sup>1</sup>H-NMR(CDCl<sub>3</sub>)  $\delta$  1.32 (t, 3H), 1.83 (d, 2H), 2.21 (m, 1H), 2.36 (m, 4H), 2.52 (m, 2H), 3.02 (m, 5H), 3.35 (m, 2H), 3.81 (s, 2H), 7.35 (m, 2H), 7.42 (m, 4H), 7.49 (m, 4H).

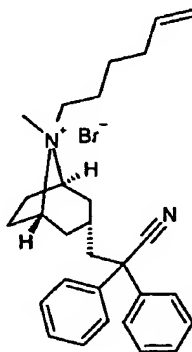
### Example 10



(3-endo)-3-(2-cyano-2,2-diphenylethyl)-8-methyl-8-propyl-8-azoniabicyclo[3.2.1]octane bromide

The title compound was prepared in 20% yield by following the general experimental procedure (reaction time = 70 hours): LCMS (ES)  $m/z$  373 (M)<sup>+</sup>; <sup>1</sup>H-NMR(CDCl<sub>3</sub>)  $\delta$  1.02 (t, 3H), 1.74 (m, 1H), 1.81 (d, 2H), 2.18 (m, 1H), 2.34 (m, 2H), 2.45 (m, 4H), 3.00 (m, 2H), 3.02 (s, 3H), 3.17 (m, 2H), 3.82 (s, 2H), 7.35 (m, 2H), 7.42 (m, 4H), 7.49 (m, 4H).

### Example 11

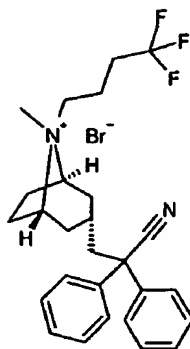


(3-endo)-3-(2-cyano-2,2-diphenylethyl)-8-(5-hexen-1-yl)-8-methyl-8-azoniabicyclo[3.2.1]octane bromide

The title compound was prepared in 29% yield by following the general experimental procedure (reaction time = 70 hours): LCMS (ES)  $m/z$  413 (M)<sup>+</sup>; <sup>1</sup>H-NMR(CDCl<sub>3</sub>)  $\delta$  1.48 (m, 2H), 1.79 (m, 4H), 2.18 (m, 3H), 2.42 (m, 6H), 3.00 (m, 5H), 3.22 (m, 2H), 3.82 (s, 2H), 5.05 (m, 2H), 5.86 (m, 1H), 7.35 (m, 2H), 7.42 (m, 4H), 7.49 (m, 4H).



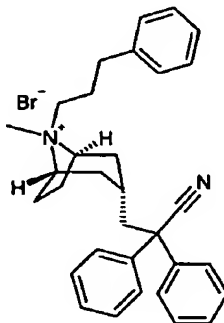
### Exempl 12



(3-endo)-3-(2-cyano-2,2-diphenylethyl)-8-methyl-8-(4,4,4-trifluorobutyl)-8-azoniabicyclo[3.2.1]octane bromide

The title compound was prepared in 23% yield by following the general experimental procedure (reaction time = 70 hours): LCMS (ES)  $m/z$  441 (M)<sup>+</sup>; <sup>1</sup>H-NMR(CDCl<sub>3</sub>)  $\delta$  1.80 (d, 2H), 2.03 (m, 2H), 2.19 (m, 1H), 2.41 (m, 8H), 3.01 (m, 2H), 3.06 (s, 3H), 3.30 (m, 2H), 3.87 (s, 2H), 7.35 (m, 2H), 7.42 (m, 4H), 7.49 (m, 4H).

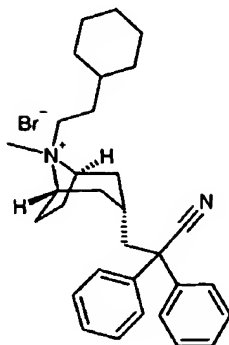
### Example 13



(3-endo)-3-(2-cyano-2,2-diphenylethyl)-8-methyl-8-(3-phenylpropyl)-8-azoniabicyclo[3.2.1]octane bromide

The title compound was prepared in 43% yield by following the general experimental procedure (reaction time = 7 days): LCMS (ES)  $m/z$  449 (M)<sup>+</sup>; <sup>1</sup>H-NMR(CDCl<sub>3</sub>)  $\delta$  1.78 (d, 2H), 2.07 (m, 2H), 2.26 (m, 4H), 2.46 (m, 3H), 2.71 (t, 2H), 2.97 (d, 2H), 2.99 (s, 3H), 3.21 (m, 2H), 3.80 (s, 2H), 7.25 (m, 2H), 7.31 (m, 4H), 7.41 (m, 5H), 7.47 (m, 4H).

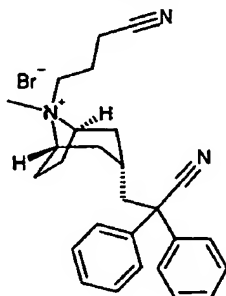
#### Example 14



(3-endo)-3-(2-cyano-2,2-diphenylethyl)-8-(2-cyclohexylethyl)-8-methyl-8-azoniabicyclo[3.2.1]octane bromide

The title compound was prepared in 21% yield by following the general experimental procedure (reaction time = 7 days): LCMS (ES)  $m/z$  441 (M)<sup>+</sup>; <sup>1</sup>H-NMR(CDCl<sub>3</sub>)  $\delta$  1.04 (m, 2H), 1.29 (m, 4H), 1.62 (m, 2H), 1.75 (m, 7H), 2.18 (m, 1H), 2.34 (m, 4H), 2.49 (m, 2H), 3.00 (m, 5H), 3.24 (m, 2H), 3.82 (s, 2H), 7.35 (m, 2H), 7.42 (m, 4H), 7.49 (m, 4H).

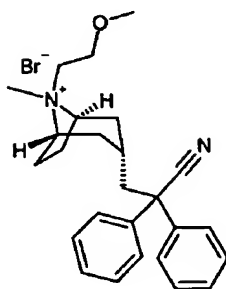
#### Example 15



(3-endo)-3-(2-cyano-2,2-diphenylethyl)-8-(3-cyanopropyl)-8-methyl-8-azoniabicyclo[3.2.1]octane bromide

The title compound was prepared in 48% yield by following the general experimental procedure (reaction time = 7 days): LCMS (ES)  $m/z$  398 (M)<sup>+</sup>; <sup>1</sup>H-NMR(CDCl<sub>3</sub>)  $\delta$  1.83 (d, 2H), 2.17 (m, 3H), 2.42 (m, 6H), 2.60 (t, 2H), 3.01 (m, 2H), 3.06 (s, 3H), 3.32 (m, 2H), 3.87 (s, 2H), 7.35 (m, 2H), 7.42 (m, 4H), 7.49 (m, 4H).

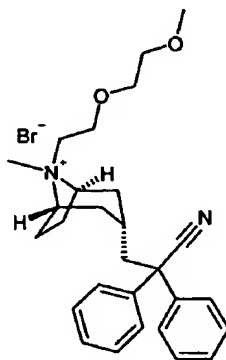
### Example 16



(3-endo)-3-(2-cyano-2,2-diphenylethyl)-8-methyl-8-[2-(methyloxy)ethyl]-8-azoniabicyclo[3.2.1]octane bromide

The title compound was prepared in 24% yield by following the general experimental procedure (reaction time = 7 days): LCMS (ES)  $m/z$  389 (M)<sup>+</sup>; <sup>1</sup>H-NMR(CDCl<sub>3</sub>)  $\delta$  1.80 (d, 2H), 2.18 (m, 1H), 2.34 (m, 2H), 2.48 (m, 4H), 3.00 (m, 2H), 3.10 (s, 3H), 3.38 (s, 3H), 3.50 (m, 2H), 3.81 (m, 2H), 3.93 (s, 2H), 7.35 (m, 2H), 7.42 (m, 4H), 7.49 (m, 4H).

### Example 17



(3-endo)-3-(2-cyano-2,2-diphenylethyl)-8-methyl-8-(2-([2-(methyloxy)ethyl]oxy)ethyl)-8-azoniabicyclo[3.2.1]octane bromide

The title compound was prepared in 28% yield by following the general experimental procedure (reaction time = 7 days): LCMS (ES)  $m/z$  433 (M)<sup>+</sup>; <sup>1</sup>H-NMR(CDCl<sub>3</sub>)  $\delta$  1.80 (d, 2H), 2.18 (m, 1H), 2.34 (m, 2H), 2.48 (m, 4H), 3.01 (m, 2H), 3.11 (s, 3H), 3.36 (s, 3H), 3.50 (m, 2H), 3.56 (m, 2H), 3.64 (m, 2H), 3.91 (m, 2H), 3.96 (s, 2H), 7.35 (m, 2H), 7.43 (m, 4H), 7.49 (m, 4H).

## **BIOLOGICAL EXAMPLES**

The inhibitory effects of compounds at the M<sub>3</sub> mAChR of the present invention are determined by the following *in vitro* and *in vivo* assay:

### **Analysis of Inhibition of Receptor Activation by Calcium Mobilization:**

Stimulation of mAChRs expressed on CHO cells were analyzed by monitoring receptor-activated calcium mobilization as previously described<sup>10</sup>. CHO cells stably expressing M<sub>3</sub> mAChRs were plated in 96 well black wall/clear bottom plates. After 18 to 24 hours, media was aspirated and replaced with 100 µl of load media (EMEM with Earl's salts, 0.1% RIA-grade BSA (Sigma, St. Louis MO), and 4 µM Fluo-3-acetoxymethyl ester fluorescent indicator dye (Fluo-3 AM, Molecular Probes, Eugene, OR) and incubated 1 hr at 37° C. The dye-containing media was then aspirated, replaced with fresh media (without Fluo-3 AM), and cells were incubated for 10 minutes at 37° C. Cells were then washed 3 times and incubated for 10 minutes at 37° C in 100 µl of assay buffer (0.1% gelatin (Sigma), 120 mM NaCl, 4.6 mM KCl, 1 mM KH<sub>2</sub> PO<sub>4</sub>, 25 mM NaH CO<sub>3</sub>, 1.0 mM CaCl<sub>2</sub>, 1.1 mM MgCl<sub>2</sub>, 11 mM glucose, 20mM HEPES (pH 7.4)). 50 µl of compound ( $1 \times 10^{-11}$  –  $1 \times 10^{-5}$  M final in the assay) was added and the plates were incubated for 10 min. at 37° C. Plates were then placed into a fluorescent light intensity plate reader (FLIPR, Molecular Probes) where the dye loaded cells were exposed to excitation light (488 nm) from a 6 watt argon laser. Cells were activated by adding 50 µl of acetylcholine (0.1-10 nM final), prepared in buffer containing 0.1% BSA, at a rate of 50 µl/sec. Calcium mobilization, monitored as change in cytosolic calcium concentration, was measured as change in 566 nm emission intensity. The change in emission intensity is directly related to cytosolic calcium levels<sup>11</sup>. The emitted fluorescence from all 96 wells is measured simultaneously using a cooled

CCD camera. Data points are collected every second. This data was then plotting and analyzed using GraphPad PRISM software.

#### **Methacholine-induced bronchoconstriction**

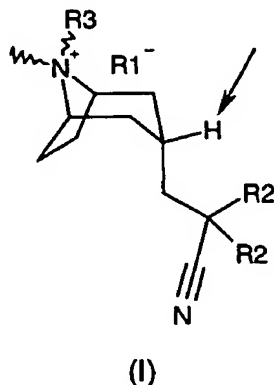
Airway responsiveness to methacholine was determined in awake, unrestrained BalbC mice ( $n = 6$  each group). Barometric plethysmography was used to measure enhanced pause (Penh), a unitless measure that has been shown to correlate with the changes in airway resistance that occur during bronchial challenge with methacholine<sup>12</sup>. Mice were pretreated with 50  $\mu$ l of compound (0.003-10  $\mu$ g/mouse) in 50  $\mu$ l of vehicle (10% DMSO) intranasally, and were then placed in the plethysmography chamber. Once in the chamber, the mice were allowed to equilibrate for 10 min before taking a baseline Penh measurement for 5 minutes. Mice were then challenged with an aerosol of methacholine (10 mg/ml) for 2 minutes. Penh was recorded continuously for 7 min starting at the inception of the methacholine aerosol, and continuing for 5 minutes afterward. Data for each mouse were analyzed and plotted by using GraphPad PRISM software.

All publications, including but not limited to patents and patent applications, cited in this specification are herein incorporated by reference as if each individual publication were specifically and individually indicated to be incorporated by reference herein as though fully set forth.

The above description fully discloses the invention including preferred embodiments thereof. Modifications and improvements of the embodiments specifically disclosed herein are within the scope of the following claims. Without further elaboration, it is believed that one skilled in the art can, using the preceding description, utilize the present invention to its fullest extent. Therefore the Examples herein are to be construed as merely illustrative and not a limitation of the scope of the present invention in any way. The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows.

What is claimed is:

1. A compound having structure I as indicated below:



wherein:

R1<sup>-</sup> represents an anion associated with the positive charge of the N atom;  
and

R2 is selected from the group consisting of straight or branched chain lower alkyl groups (having preferably from 1 to 6 carbon atoms), cycloalkyl groups (having from 5 to 6 carbon atoms), cycloalkyl-alkyl (having 6 to 10 carbon atoms), heterocycloalkyl (having 5 to 6 carbon atoms) and N or O as the heteroatom, heterocycloalkyl-alkyl (having 6 to 10 carbon atoms) and N or O as the heteroatom, aryl, optionally substituted aryl, heteroaryl, and optionally substituted heteroaryl;

R3 is selected from the group consisting of (C<sub>2</sub>-C<sub>12</sub>)alkyl, (C<sub>1</sub>-C<sub>6</sub>)alkenyl, (C<sub>1</sub>-C<sub>6</sub>)alkyl(C<sub>3</sub>-C<sub>6</sub>)cycloalkyl, (C<sub>1</sub>-C<sub>6</sub>)alkyl-phenyl, (C<sub>1</sub>-C<sub>6</sub>)alkyl-OH, (C<sub>1</sub>-C<sub>6</sub>)alkyl-CN, (C<sub>1</sub>-C<sub>6</sub>)alkyl-halogen, (C<sub>1</sub>-C<sub>6</sub>)alkyl-CF<sub>3</sub>, (C<sub>1</sub>-C<sub>6</sub>)alkyl-OCH<sub>3</sub>, and (C<sub>1</sub>-C<sub>6</sub>)alkyl-O-(C<sub>1</sub>-C<sub>6</sub>)alkyl-OCH<sub>3</sub>.

2. A compound according to claim 1 wherein the H atom indicated is in the exo position.

3. A compound according to claim 1 wherein R1<sup>-</sup> is selected from the group consisting of chloride, bromide, iodide, sulfate, benzene sulfonate and toluene sulfonate.

4. A compound according claim 1 selected from the group consisting of:

(3-endo)-3-(2-cyano-2,2-diphenylethyl)-8-(cyclohexylmethyl)-8-methyl-8-azoniabicyclo[3.2.1]octane bromide;

(3-endo)-3-(2-cyano-2,2-diphenylethyl)-8-(cyclopropylmethyl)-8-methyl-8-azoniabicyclo[3.2.1]octane bromide;

(3-endo)-8-butyl-3-(2-cyano-2,2-diphenylethyl)-8-methyl-8-azoniabicyclo[3.2.1]octane bromide;

(3-endo)-8-(4-chlorobutyl)-3-(2-cyano-2,2-diphenylethyl)-8-methyl-8-azoniabicyclo[3.2.1]octane bromide;

(3-endo)-3-(2-cyano-2,2-diphenylethyl)-8-dodecyl-8-methyl-8-azoniabicyclo[3.2.1]octane bromide;

(3-endo)-3-(2-cyano-2,2-diphenylethyl)-8-methyl-8-(2-propen-1-yl)-8-azoniabicyclo[3.2.1]octane iodide;

(3-endo)-3-(2-cyano-2,2-diphenylethyl)-8-methyl-8-(phenylmethyl)-8-azoniabicyclo[3.2.1]octane bromide;

(3-endo)-3-(2-cyano-2,2-diphenylethyl)-8-(2-hydroxyethyl)-8-methyl-8-azoniabicyclo[3.2.1]octane bromide;

(3-endo)-3-(2-cyano-2,2-diphenylethyl)-8-ethyl-8-methyl-8-azoniabicyclo[3.2.1]octane bromide;

(3-endo)-3-(2-cyano-2,2-diphenylethyl)-8-methyl-8-propyl-8-azoniabicyclo[3.2.1]octane bromide;

(3-endo)-3-(2-cyano-2,2-diphenylethyl)-8-(5-hexen-1-yl)-8-methyl-8-azoniabicyclo[3.2.1]octane bromide;

(3-endo)-3-(2-cyano-2,2-diphenylethyl)-8-methyl-8-(4,4,4-trifluorobutyl)-8-azoniabicyclo[3.2.1]octane bromide;

(3-endo)-3-(2-cyano-2,2-diphenylethyl)-8-methyl-8-(3-phenylpropyl)-8-azoniabicyclo[3.2.1]octane bromide;

(3-endo)-3-(2-cyano-2,2-diphenylethyl)-8-(2-cyclohexylethyl)-8-methyl-8-azoniabicyclo[3.2.1]octane bromide;  
(3-endo)-3-(2-cyano-2,2-diphenylethyl)-8-(3-cyanopropyl)-8-methyl-8-azoniabicyclo[3.2.1]octane bromide;  
(3-endo)-3-(2-cyano-2,2-diphenylethyl)-8-methyl-8-[2-(methyloxy)ethyl]-8-azoniabicyclo[3.2.1]octane bromide; and  
(3-endo)-3-(2-cyano-2,2-diphenylethyl)-8-methyl-8-(2-{{2-(methyloxy)ethyl}oxy}ethyl)-8-azoniabicyclo[3.2.1]octane bromide.

5. A pharmaceutical composition for the treatment of muscarinic acetylcholine receptor mediated diseases comprising a compound according to claim 1 and a pharmaceutically acceptable carrier thereof.

6. A method of inhibiting the binding of acetylcholine to its receptors in a mammal in need thereof comprising administering a safe and effective amount of a compound according to claim 1.

7. A method of treating a muscarinic acetylcholine receptor mediated disease, wherein acetylcholine binds to said receptor, comprising administering a safe and effective amount of a compound according to claim 1.

8. A method according to claim 7 wherein the disease is selected from the group consisting of chronic obstructive lung disease, chronic bronchitis, asthma, chronic respiratory obstruction, pulmonary fibrosis, pulmonary emphysema and allergic rhinitis.

9. A method according to claim 8 wherein administration is via inhalation via the mouth or nose.



10. A method according to claim 9 wherein administration is via a medicament dispenser selected from a reservoir dry powder inhaler, a multi-dose dry powder inhaler or a metered dose inhaler.
11. A method according to claim 10 wherein the compound is administered to a human and has a duration of action of 12 hours or more for a 1 mg dose.
12. A method according to claim 11 wherein the compound has a duration of action of 24 hours or more.
13. A method according to claim 12 wherein the compound has a duration of action of 36 hours or more.

## **ABSTRACT OF THE DISCLOSURE**

Muscarinic Acetylcholine receptor antagonists and methods of using them are provided.

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